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RESPONSE OF THINNED PONDEROSA PINE TO FERTILIZATION

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ABSTRACT

Rates of height, basal area, volume, and bole area growth of thinned ponderosa pine were increased more than 50 percent by applications of nitrogren, phosphorus, and sulfur during the first 5-year period after application. Height growth was not related to stand density, but rates of volume and bole area growth were definitely correlated with basal area at the start of treatment.

KEYWORDS: Fertilizer response (forest tree), increment (volume), increment (height), ponderosa pine, *Pinus ponderosa*.

INTRODUCTION

How fast will thinned ponderosa pine (*Pinus ponderosa*) stands grow when fertilized repeatedly? This question becomes increasingly important as the land base available for intensive timber management continues to shrink while rising energy costs escalate prices of fertilization and other stand treatments. Both thinning and fertilization can substantially increase growth of remaining trees in the stand (Barrett 1973, Cochran 1978). Fertilization without thinning is not recommended since much of the increased growth may be by trees that will never reach marketable size. Response to fertilization lasts at least 4 years and possibly more than 8 years on some sites (Cochran 1977). To attempt to improve growth, I applied moderate amounts of fertilizer at 5-year intervals to plots in a ponderosa pine stand that had been precommercially thinned. The stand is representative of large areas on the Deschutes National Forest in central Oregon. This note compares growth rates of the fertilized and unfertilized treatments for the first 5-year period after initial application.

METHODS OF STUDY

Study Area

The study area is located approximately 20 miles south of Bend, Oregon.[1] Elevations range from 4,400 to 4,600 feet. Summers are very dry, and annual precipitation is approximately 24 inches. Topography of the area is gently sloping (2 to 7 percent), mostly to the west. The soil (Shanahan series) is a Typic Cryandept developing on Mazama pumice and ash.[2] The A1 horizon is 2 inches

[1] For metric equivalents, see page 8.

[2] For chemical and physical properties of some Shanahan soils, see Cochran (1973, 1977).

thick, and the AC horizon overlies an older, buried sandy loam at 26 to 32 inches. The predominant understory shrub is bitterbrush (*Purshia tridentata*), but some manzanita (*Arctostaphylos patula*) and snowbrush (*Ceanothus velutinus*) shrubs are present. Fescue (*Festuca idahoensis*) and needlegrass (*Stipa occidentalis*) are the predominant grasses.

The area was railroad logged in the 1920's, and the present stand had an average breast-high age of 34 years in 1974. Site index varies from 84 to 108 feet over the study site (Barrett 1978). The stand was thinned to an average spacing of about 17 feet (151 trees/acre) in 1972, and the slash was tomahawked in the late summer and fall of 1973.[3] The slash treatment reduced the understory vegetation to less than 5-percent cover.

Design and Installation

A completely randomized design with two treatments (control and fertilization) was installed. Twenty-four 0.2-acre plots with 33-foot buffer strips were established in the fall of 1973. Additional thinning was done on some of the plots and their buffer strips to provide a wider range in stand densities than normally found after precommercial thinning. Trees were tagged, d.b.h.'s were measured, and the basal areas were calculated for each plot. Twelve plots were randomly chosen for fertilization. Just before snowfall in 1973, nitrogen (N), phosphorus (P), and sulfur (S) at rates equivalent to 200 lb/acre N, 100 lb/acre P, and 33 lb/acre S were applied to each of these plots in the form of ammonium sulfate, urea, and triple super phosphate.[4]

Measurements

At least 15 trees in each 0.2-acre plot were measured in the fall of 1973 and again in the fall of 1978 with optical dendrometers. Trees selected for measurement with a dendrometer encompassed the range of diameter classes. All forked trees were also measured with a dendrometer. Heights (h) of all trees not measured with dendrometers were measured with height poles. Diameter tapes were used for all d.b.h.'s (d). Volumes and bole areas above a 1-foot stump for the trees measured with a dendrometer were determined by Grosenbaugh's (1967) STX program with a modification of one of Brickell's (1970) equations to convert diameters outside bark to diameters inside bark (Cochran 1976). Equations relating volume (V) and bole area were developed from the nonforked trees measured with a dendrometer on each plot at the start and also at the end of the first 5-year period:

$$V = a + b\,(d^2h);$$

$$\text{Bole area} = a_1 + b_1\,(dh);$$

where

a, b, and a_1 and b_1 are regression coefficients.

These equations were then used to determine volumes and bole areas for trees on corresponding plots not measured with optical dendrometers. Basal areas, bole areas, volumes, heights, and diameters were computed for each plot at the end of the growing seasons in 1973 and 1978 (tables 1 and 2), and differences divided by 5 were used for average annual growth rates.

Statistical Analysis

Analysis of covariance was used to test the hypothesis that fertilization did not increase growth. The covariate was basal area at the start of the 5-year growing period. At 5-percent level of probability was chosen for determining significant differences in slopes or adjusted means.

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[3] Tomahawking is a method for reducing fire hazard in slash by mechanical crushing with an implement called "Tomahawk" mounted on the front of a crawler tractor (Dell and Ward 1969).

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[4] Triple super phosphate also contains 12 percent calcium and 1 percent sulfur. Calcium is not a limiting element in this soil.

Table 1--Some estimates for the fertilized and control plots at the start of the study

Plot number	Basal area	Bole area[1/]	Volume[1/]	Average height	Average diameter[2/]	Trees per acre
	Square feet per acre		Cubic feet per acre	Feet	Inches	Number
Fertilized:						
11	80.5	10,094.5	1,184.0	39.5	7.9	225
1	78.0	8,744.0	1,151.5	39.4	8.7	180
18	67.0	7,801.5	958.5	39.0	8.4	170
10	64.5	7,951.0	1,020.0	41.3	8.6	155
2	55.5	6,002.0	721.5	34.4	8.0	150
13	51.0	6,737.5	719.5	38.5	7.5	165
22	45.8	5,319.0	585.0	33.6	7.3	150
24	45.5	5,201.5	584.5	33.1	7.3	150
17	41.0	4,492.0	492.5	31.3	7.2	140
9	39.5	4,832.0	511.5	34.2	7.0	140
20	29.8	3,323.5	345.0	32.9	7.3	100
15	28.1	3,071.5	320.5	30.5	7.1	100
Control:						
21	79.5	9,177.0	1,061.5	36.4	7.9	225
19	79.0	8,792.0	1,126.5	37.0	8.2	200
12	63.0	8,166.0	943.5	42.1	8.2	170
3	62.5	6,793.3	859.5	34.8	7.9	170
5	60.5	6,148.5	740.0	33.4	8.0	165
4	54.5	5,979.0	756.0	34.9	8.2	140
23	54.5	5,847.0	633.0	32.3	7.2	180
7	48.5	6,084.0	678.0	37.0	7.5	150
16	41.5	4,647.0	509.0	32.2	7.2	140
8	35.0	4,404.5	449.0	33.8	6.7	135
14	27.0	3,115.5	338.5	30.9	6.8	100
6	23.5	2,811.0	269.5	30.4	6.5	100

[1/] Values do not include bole areas and volumes of 1-foot stumps.

[2/] This diameter is the actual mean diameter and is not the diameter derived from the average basal area.

Table 2--Some estimates for the fertilized and control plots 5-growing seasons after the start of the study

Plot number	Basal area	Bole area[1]	Volume[1]	Average height	Average diameter[2]	Trees per acre
	Square feet per acre		Cubic feet per acre	Feet	Inches	Number
Fertilized:						
11	106.0	13,125.5	1,744.0	45.1	9.1	225
1	95.0	11,125.0	1,610.0	44.9	9.6	180
18	90.0	10,151.0	1,400.5	44.8	9.7	170
10	85.0	10,367.5	1,510.5	47.1	9.9	155
2	80.5	8,475.0	1,222.5	41.0	9.7	150
13	70.0	9,094.0	1,141.0	43.4	8.8	165
22	65.0	7,264.5	922.0	39.3	8.8	150
24	63.0	7,201.5	944.0	38.5	8.6	150
17	59.0	6,132.0	771.0	36.7	8.7	140
9	58.5	6,833.5	880.5	40.0	8.5	140
20	47.5	5,041.0	663.0	39.4	9.3	100
15	46.5	4,540.5	615.5	36.9	9.2	100
Control:						
21	95.5	11,041.0	1,385.0	40.9	8.7	225
19	93.0	10,331.0	1,403.0	40.9	8.9	200
12	74.5	9,625.0	1,199.0	46.1	9.1	170
3	77.0	8,240.0	1,107.5	38.3	8.8	170
5	75.5	7,703.0	1,008.0	37.6	8.9	165
4	67.5	7,059.0	948.0	39.5	9.2	140
23	69.0	7,358.0	884.5	35.9	8.2	180
7	61.0	7,488.0	934.0	40.8	8.5	150
16	57.0	6,107.0	777.5	36.4	8.5	140
8	44.0	5,390.0	618.5	33.6	7.5	135
14	36.0	3,764.0	477.0	34.4	7.3	100
6	34.0	3,657.5	411.0	32.3	7.8	100

[1] Values do not include bole areas and volumes of 1-foot stumps.

[2] This diameter is the actual mean diameter and is not the diameter derived from the average basal area.

RESULTS AND DISCUSSION

The average and range of correlation coefficients (r^2) and standard errors for the volume and bole area equations determined for 20 of the 24 plots were:[5]

	1974	
	r^2	Standard error ft^3/acre per year
Volume:		
Average	0.9671	0.46
Range	0.8885-.9975	0.22-.70
		ft^2/acre per year
Bole area:		
Average	.9723	2.3
Range	.9288-.9952	1.1-3.3

	1978	
	r^2	Standard error ft^3/acre per year
Volume:		
Average	0.9693	0.63
Range	0.8925-.9936	0.26-1.37
		ft^2/acre per year
Bole area:		
Average	.9795	2.6
Range	.9411-.9941	1.3-4.7

These high r^2 values and low standard errors indicate that the predictive equations for volume and bole area, developed from a subsample of 15 trees on each plot, were adequate for determining volumes and bole areas of the remaining plot trees.

As expected, no mortality occurred during the 5-year period after initial treatment. Fertilization significantly increased all determined growth rates, including height (figs. 1-4). Adjusted means of average annual growth rates for the control and fertilization treatments were:

	Control	Fertilized	Increase (Percent)
Volume growth (ft^3/acre per year)	46.4	80.6	74
Basal area growth (ft^2/acre per year)	2.6	4.0	54
Bole area growth (ft^2/acre per year)	262.9	429.8	63
Height (ft/year)	.74	1.15	55

Average annual height growth ranged from 0.4 to 0.9 foot/year for the control plots and 1 to 1.3 feet/year for the fertilized plots.

The relationship of height growth to stand density during this initial 5-year period is not clear (fig. 4). Above initial densities of 40 square feet of basal area per acre, height growth on control plots appears unaffected by initial density. At lower densities, height growth may have been reduced on the control plots. Oliver (1979) observed height growth of pole-size ponderosa pine in California over a 15-year period. He found that for the first 5-year period after thinning, there was no correlation between height growth and stand density. During the second 5-year period, there was a tendency for height growth to be reduced by stand density; but the correlation was not statistically significant. For the third 5-year period after thinning, height growth significantly decreased with stand basal area.

The significant increases in growth obtained in this study resulted from a combination of N, P, and S. Results from another study (Cochran 1978) show that most of the response is due to nitrogen. In that study, S and P in combination with N tended to increase volume production; but increases in volume were not significant at the 5-percent level of probability. Further evidence from the earlier study suggests but does not conclusively prove that S is more important than P (in combination with N) for increasing volume production. For land managers wishing to fertilize thinned ponderosa pine stands on soils developing from Mazama pumice or ash, I tentatively recommend a single application of 200 pounds of elemental N and 30 pounds of elemental S per acre. This recommendation may change as results from continued studies become available. Foresters can expect definite responses to N and S, noticeable on increment cores, which will last at least 5 years and possibly more than 8.

[5] Four plots had just 20 trees (100 trees/acre, tables 1 and 2). All the trees in these plots were measured with dendrometers, and no equations were necessary for total volumes and bole areas.

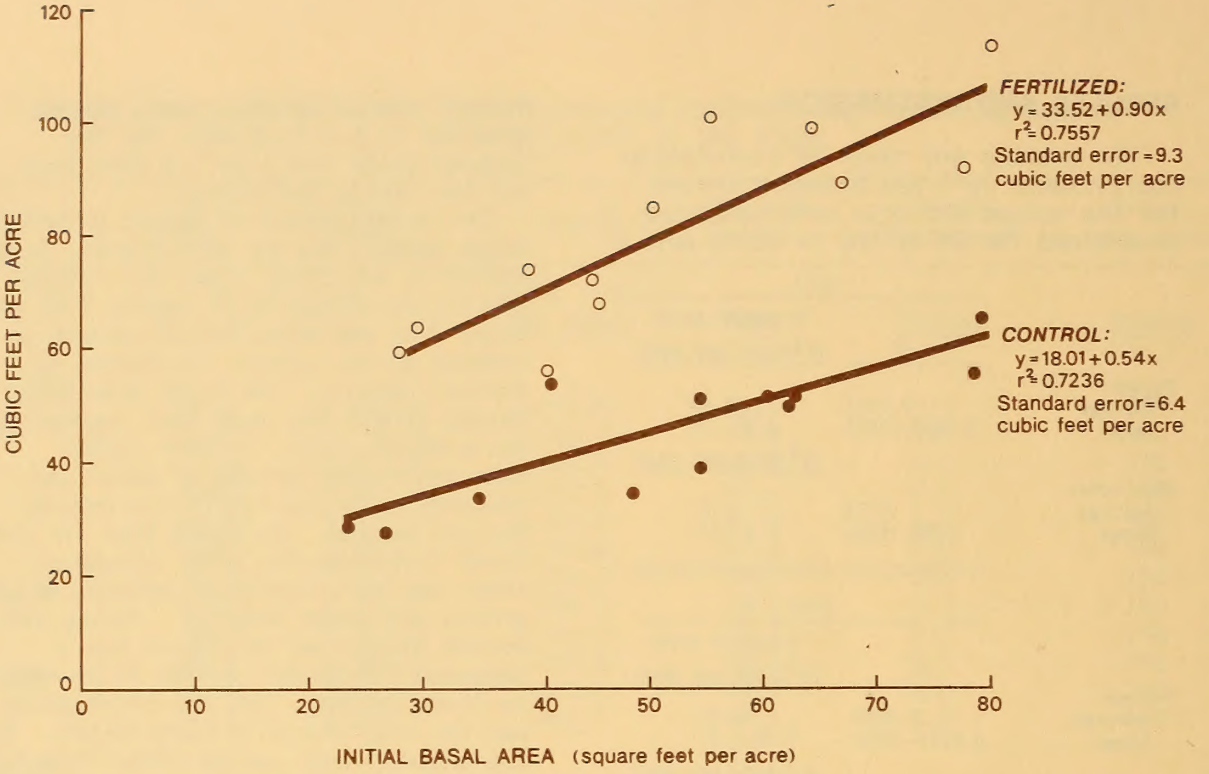

Figure 1.--Average annual volume growth during the 1974-78 growing seasons as a function of basal area at the start of 1974. Differences in slopes of the regression lines are not significant, but the adjusted mean for the fertilizer treatment is significantly greater.

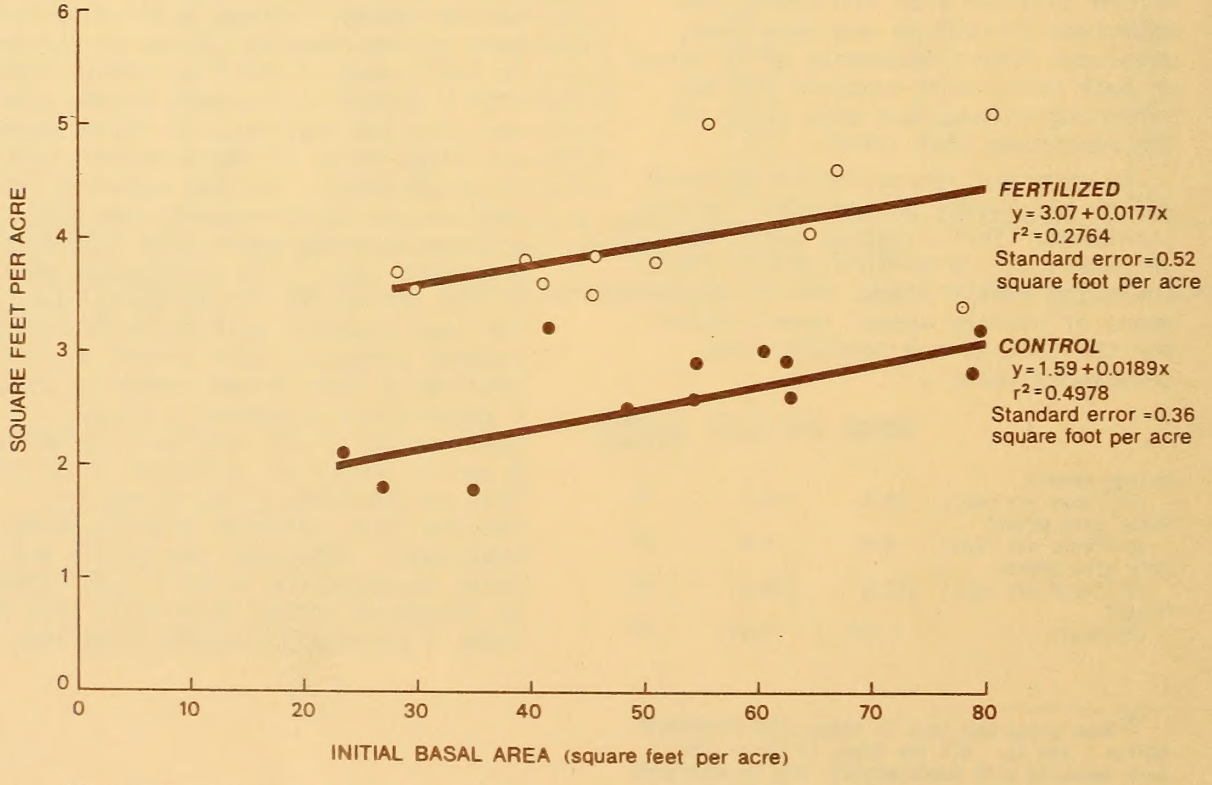

Figure 2.--Average annual basal area growth during the 1974-78 growing seasons as a function of basal area at the start of 1974. Slopes of the regression lines are not significantly different, but the adjusted means are significantly different.

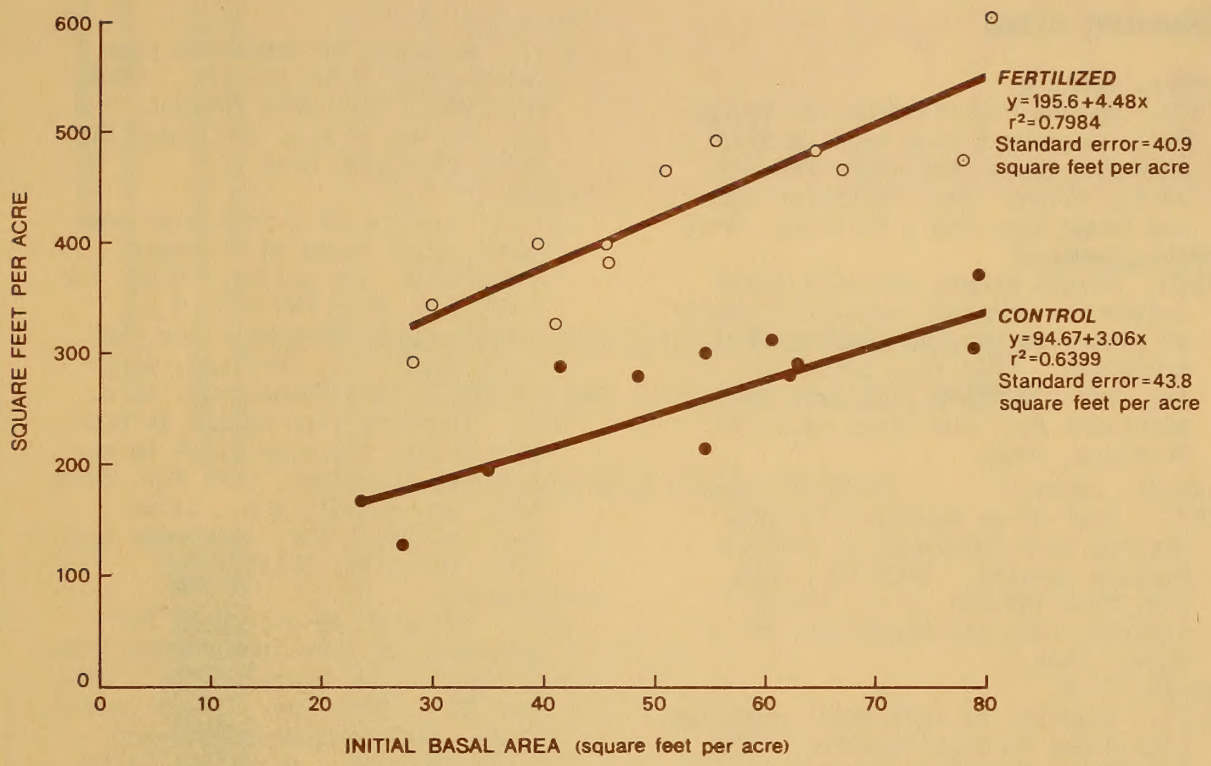

Figure 3.--Average annual bole area growth during the 1974-78 growing seasons as a function of basal area at the start of 1974. Slopes of the regression lines are not significantly different, but the adjusted means are significantly different.

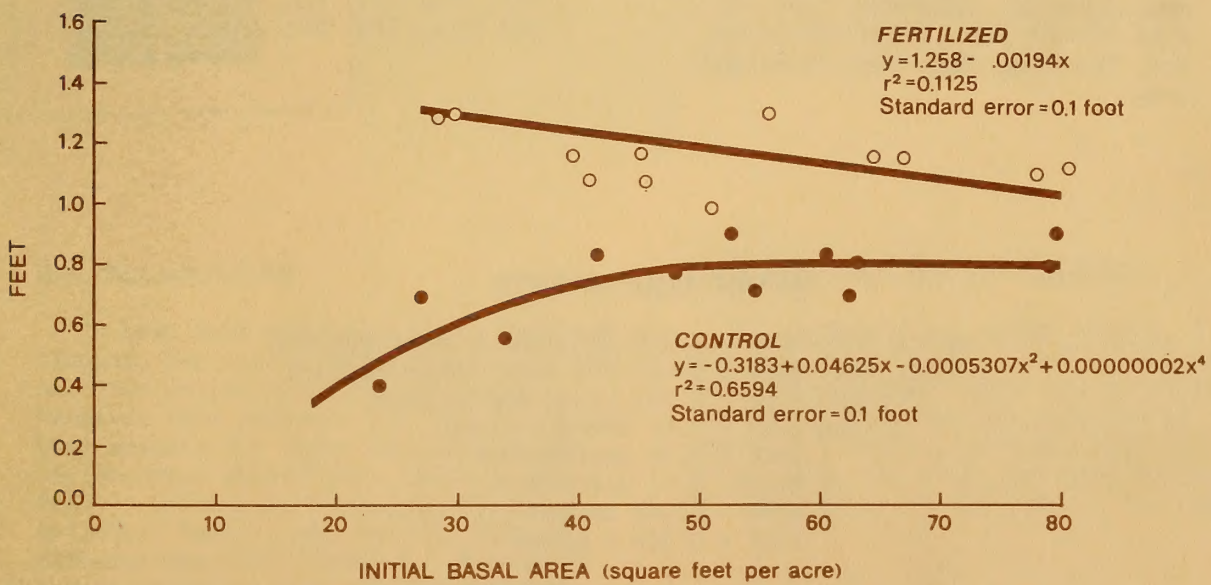

Figure 4.--Average annual height growth during the 1974-78 growing seasons as a function of initial basal area at the start of 1974. Adjusted means for the fertilized plots are significantly higher. The regression for the fertilized plots is not significant.

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METRIC EQUIVALENTS

1 square foot/acre = 0.229 568 square meter/hectare
1 cubic foot/acre = 0.069 972 cubic meter/hectare
1 pound/acre = 1.121 kilograms/hectare
1 tree/acre = 2.47 trees/hectare
1 inch = 2.54 centimeters
1 mile = 1.61 kilometers
1 acre = 0.405 hectare
1 foot = 0.304 8 meter

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